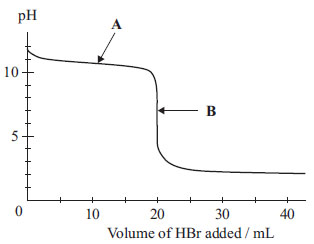
Titration curves

**1)** A titration was carried out by adding hydrobromic acid, HBr, to 20.0 mL of aqueous methylamine, CH3NH2, solution.

The equation for the reaction is: CH3NH2 + HBr → CH3NH3+ + Br–

*K*a(CH3NH3+) = 2.29 × 10–11

The curve for this titration is given below:



(a) Explain why the pH does not change significantly between the addition of 5 to 15 mL of HBr (around

point **A** on the curve). Include any relevant equation(s) in your answer.

(b) The aqueous methylamine, CH3NH2, solution has a pH of 11.8 before any HBr is added.

Show by calculation that the concentration of this solution is 0.0912 mol L–1.

(c) (i) Write the formulae of the four chemical species, apart from water and OH–, that are present at the point marked **B** on the curve.

(ii) Compare and contrast the solution at point **B** with the initial aqueous methylamine solution.

In your answer you should include:

• a comparison of species present AND their relative concentrations

• a comparison of electrical conductivity linked to the relevant species present in each solution

• equations to support your answer.

**2)** 20.0 mL of 0.0896 mol L–1 ethanoic acid is titrated with 0.100 mol L–1 sodium hydroxide.

p*K*a (CH3COOH) = 4.76

(a) Calculate the pH of the ethanoic acid before any NaOH is added.

(b) Halfway to the equivalence point of the titration, the pH = p*K*a of the ethanoic acid.

Discuss the reason for this.

(c) (i) Discuss the change in the concentration of species in solution, as the first 5.00 mL of NaOH is added

to the 20.0 mL of ethanoic acid. Your answer should include chemical equations.

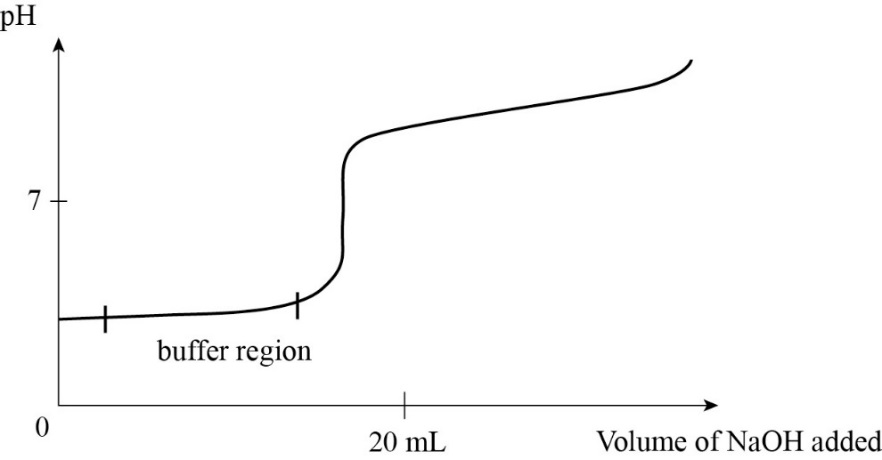
No calculations are required.

(ii) Calculate the pH of the titration mixture after 5.00 mL of NaOH has been added.

**3)** 20.00 mL of 0.125 mol L–1 ethanoic acid is titrated with 0.125 mol L–1 sodium hydroxide solution. The equation for this reaction is:

CH3COOH(*aq*) + NaOH(*aq*) 🡪 CH3COONa(*aq*) + H2O (*l*)

The titration curve for the reaction is given below and the buffer region is marked on the graph.



1. (i) Explain why the solution in the titration flask can act as a buffer in this marked region. Use an equation in your answer.

(ii) Put an **X** on the graph to show at which point the buffering action is the most efficient. Give reasons for your answer.

1. (i) Show that the pH at the equivalence point for this titration is 8.78.

p*K*a(CH3COOH ) = 9.24

(ii) Explain why methyl orange is not a suitable indicator for this titration and why phenolphthalein is a suitable indicator for this titration

|  |  |
| --- | --- |
| **Indicator** | **p*K*a** |
| Methyl orange | 3.70 |
| Phenolphthalein | 9.30 |

Phenolphthalein is an acid-base indicator. It is a weak acid and its formula can be represented as HIn. Phenolphthalein is colourless in acidic solutions and purple in basic solutions.

p*K*a (HIn) = 9.60

Discuss the effect of adding ethanoic acid and sodium hydroxide in turn to a solution containing phenolphthalein. In your answer, you should refer to:

* equilibrium principles
* the species responsible for the colours seen
* the pH range within which this indicator is effective.

**4)** A titration was carried out with methanoic acid and sodium hydroxide.

The equation for the reaction is: HCOOH + NaOH → HCOONa + H2O p*K*a (HCOOH) = 3.74

The curve for this titration is given below:



25.0 mL of methanoic acid solution is titrated with 0.180 mol L–1 sodium hydroxide.

**a) i)** Show that the concentration of the HCOOH solution is 0.288 mol L–1.

**ii)** **Calculate** the initial pH of the 0.288 mol L–1 HCOOH solution.

**b)** Discuss the pH of the reaction mixture, in terms of the species present, after 20 mL of NaOH has been

added. *No calculations are necessary.*

**c)** Some indicators and their p*K*a values are shown in the table below.



Discuss the suitability of **each** of these indicators for this titration.

In your answer you should include:

• an identification of the most suitable indicator(s)

• the consequences of choosing an unsuitable indicator

• an explanation of the significance of the p*K*a in selecting an indicator.

**5)** Below is the titration curve for 10.0 mL of 0.100 mol L–1 ethanoic acid being titrated with 0.100 mol L–1 sodium hydroxide. Ethanoic acid can be represented by the symbol HEt.



**a)** With reference to the point marked **A** on the graph, discuss:

• the species present, and their relative concentrations

• an estimate of the p*K*a value for ethanoic acid

• the effect of adding small amounts of strong acid or strong base to the solution.

*Include relevant equations in your answer. No calculations are necessary.*

**b)** With reference to the point marked **B** on the graph, discuss the species present, and their effect on the pH

at the equivalence point.

*Include relevant equations in your answer. No calculations are necessary.*

**6)** 20.00 mL of 0.160 mol L–1 ammonia is titrated with 0.230 mol L–1 hydrochloric acid.

The equation for the reaction is

NH3 + HCl → NH4+ + Cl–

p*K*a(NH4+) = 9.24, *K*a = 5.75 × 10–10

The curve for this titration is given below.



**a)** Explain, in terms of species present, why the pH at **B** (half way to the equivalence volume) is 9.24.

**b)** Calculate the pH at point **A**.

**c)** Discuss the pH of the reaction mixture at point **C**, in terms of the species present.

**7)** 25.0 mL of 0.0500 mol L–1 benzoic acid solution (C6H5COOH) is titrated with 0.0500 mol L–1 sodium hydroxide solution. The equation for the reaction is:

C6H5COOH(*aq*) + NaOH(*aq*) → C6H5COONa(*aq*) + H2O(*ℓ*)

The titration curve for the reaction is:



**a)** Write the formulae of the four chemical species, apart from water and H3O+, that are present at the equivalence point.

**b)** Explain why the solution in the titration flask has buffering properties after 9.80 mL of the NaOH solution has been added, but not when 25.0 mL has been added.

**c)** Some indicators are shown in the table below.



Discuss the suitability of these indicators for this titration.

Your discussion should include:

• identification of the most suitable indicator(s)

• consideration of how indicators are chosen for a titration

• the consequences of choosing an unsuitable indicator.

**8)** The following titration curve shows the addition of aqueous 0.100 mol L–1 sodium hydroxide to a solution of hydrazoic acid, HN3.

p*K*a(HN3) = 4.72



**a) i)** Draw a cross (X) on the titration curve to indicate the pH at the equivalence point of the titration.

**ii)** Complete the titration curve to show how the pH changes as more aqueous sodium hydroxide is added.

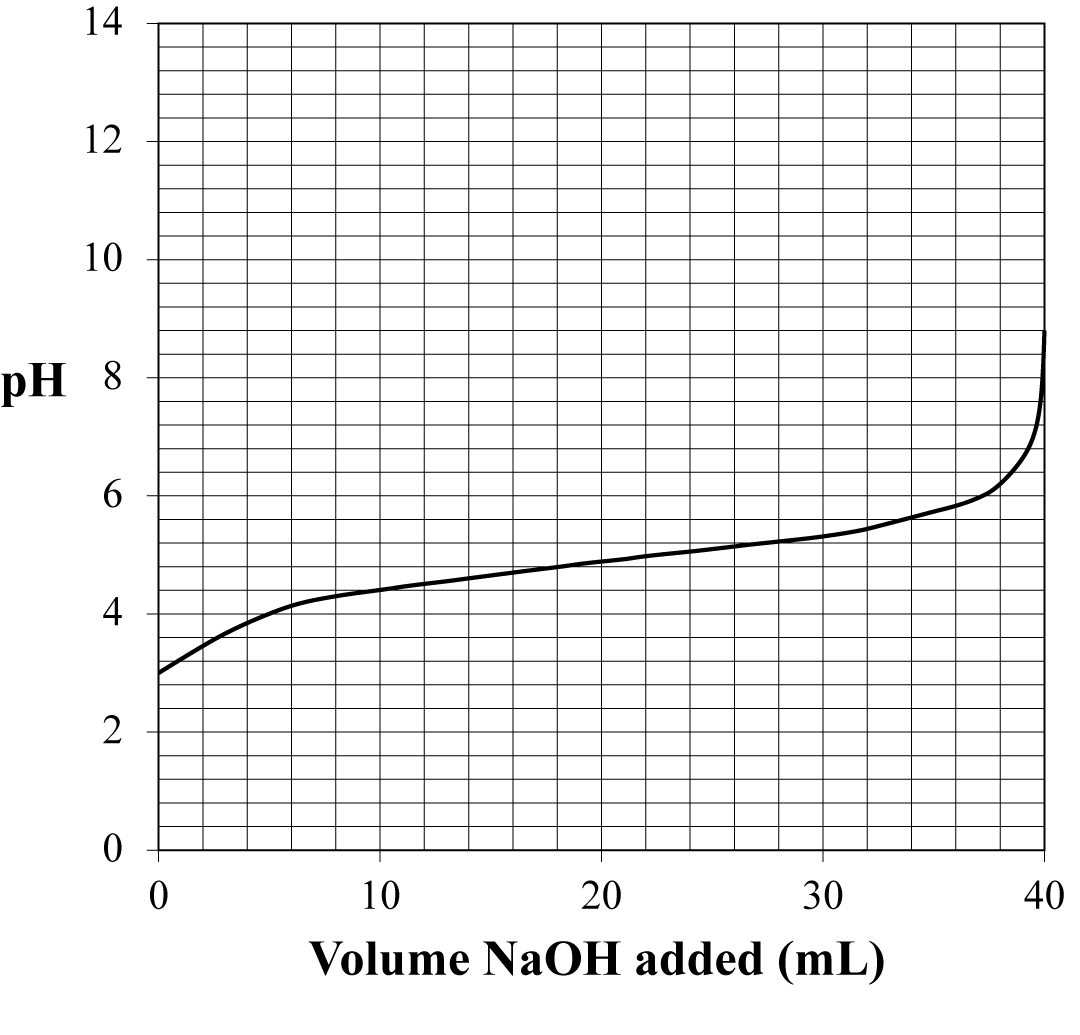
**b)** The initial pH of the hydrazoic acid (HN3) is 2.6. Calculate the concentration of the HN3 solution used in

the titration.

**9)** A 0.160 mol L–1 solution of sodium hydroxide is titrated against 50 mL of aqueous propanoic acid, HPr. 40 mL of the sodium hydroxide solution was required to exactly react with the propanoic acid.

The reaction occurring can be represented as: HPr(*aq*) + NaOH(*aq*) → NaPr(*aq*) + H2O

*K*a(HPr) = 1.35 × 10–5



**a) i)** Show that the concentration of the aqueous propanoic acid is 0.128 mol L–1.

**ii)** Calculate the pH of the aqueous propanoic acid.

**b)** Calculate the pH at the equivalence point.

**c)** 35 mL of the sodium hydroxide solution is added to a second 50 mL sample of the same acid to form a

buffer solution.

**i)** What is the function of a buffer?

**ii)** Discuss the ability of the solution formed to act as a buffer. Your answer should include relevant

equations.

**d)** The equivalence point of the titration could also be found using an acid-base indicator.

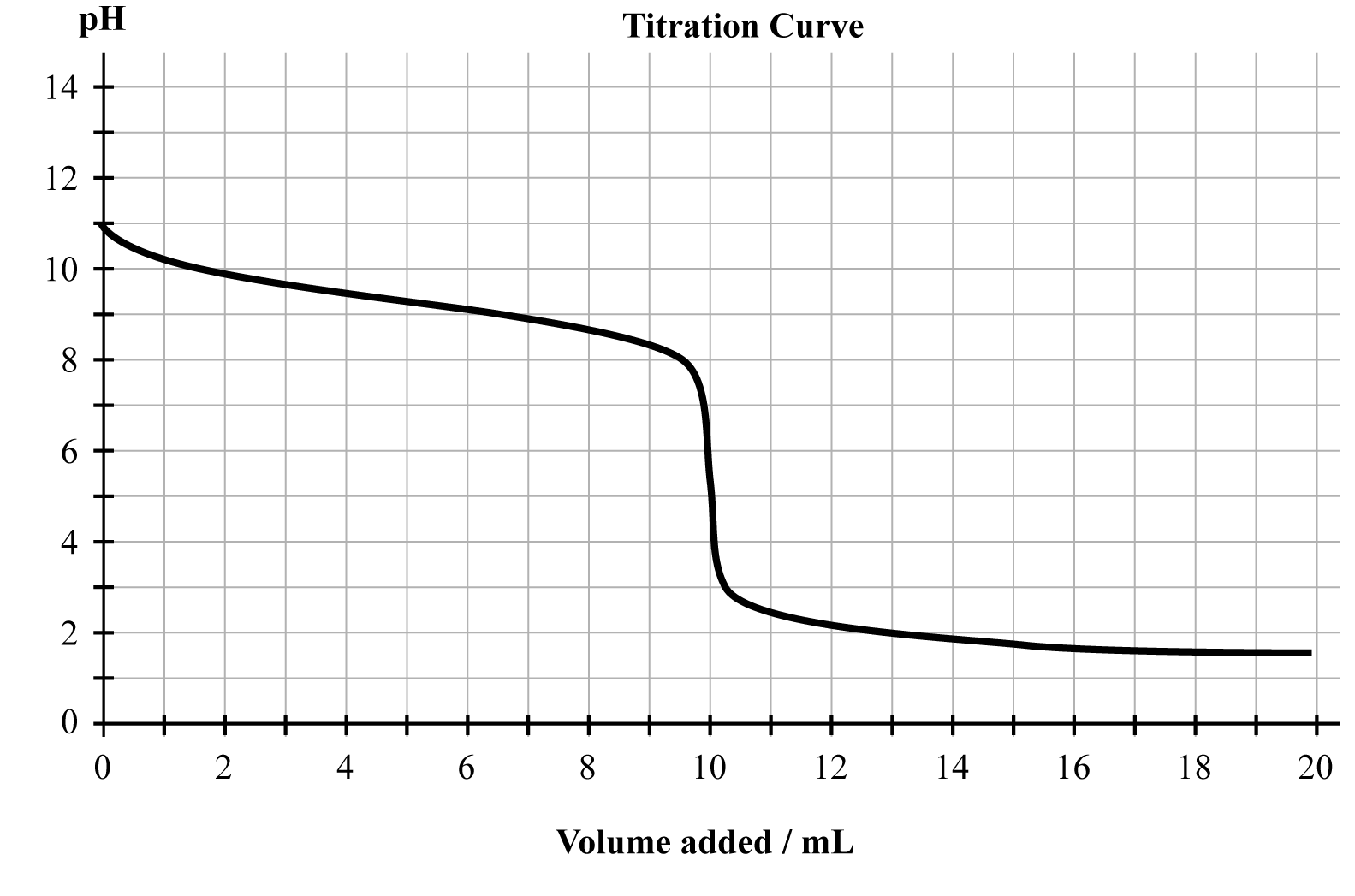
Which of the following indicators would be suitable to use? Explain your choice of indicator.

|  |  |
| --- | --- |
| **Indicator** | **p*K*a** |
| Methyl orange | 3.7 |
| Bromocresol green | 4.7 |
| Methyl red | 5.0 |
| Thymol blue | 8.9 |
| Phenolphthalein | 9.3 |

**10)** The graph below shows the change in pH when 40.0 mL of 0.0500 mol L–1 aqueous NH3 is titrated with 0.200 mol L–1 aqueous HCl.

The equation for the reaction occurring during the titration is:

NH3(*aq*) + HCl(*aq*) → NH4Cl(*aq*)



**a)** Use the curve to determine p*K*a(NH4+) and hence calculate *K*a(NH4+).

**b)** Explain why the pH at the equivalence point for this titration is less than 7. (Include an equation to

support your answer.)

A NH4+/NH3 buffer solution is prepared with a pH of 9.6.

**c)** Use the graph to describe how this buffer solution could be made from 0.0500 mol L–1 NH3 solution and

0.200 mol L–1 HCl solutions.

A second titration is carried out – this time 40.0 mL of 0.0500 mol L–1 NH4Cl solution is titrated against 0.200 mol L–1 NaOH solution.

**d)** Write an equation for the titration reaction.

**e) i)** Show that [NH3] at the equivalence point is 0.0400 mol L–1.

**ii)** Using *K*a(NH4+) determined in part (a) on the previous page, determine the pH at the equivalence point

of the second titration.

**11)** The active ingredient in many sunscreens is *para*-aminobenzoic acid. It is a weak monoprotic acid

and can be represented as HPab, while its conjugate base is Pab–.

**a)** Write an equation for the reactions occurring at equilibrium when HPab is dissolved in water.

**b)** Write the expression for *K*a(HPab).

A solution of HPab in water was prepared at 25°C and its pH was found to be 3.22.

**c)** Calculate the concentration of H3O+ in the solution.

**d)** The concentration of the HPab solution was determined by titration. A 20.0 mL sample of the HPab solution required 12.0 mL of 0.0500 mol L–1 NaOH to reach the equivalence point. The equation for the reaction occurring is

HPab + NaOH → NaPab + H2O

**i)** Calculate the concentration of the HPab solution.

**ii)** Using the results from parts (c) and (d)(i), show that p*K*a(HPab) = 4.92.

**e)** Would the pH at the equivalence point of the titration of HPab with NaOH be more than 7,

less than 7 or equal to 7? Give reasons and include any relevant equations that support your

answer.

**f)** Using the information above, sketch a curve showing the change in pH against the volume of

sodium hydroxide added to the 20.0 mL HPab solution in the flask.



© 2015 <http://www.chemicalminds.wikispaces.com>

NCEA questions and answers reproduced with permission from NZQA